Evaluation of Bus Routes Efficiency Using Data Envelopment Analysis (DEA) and Free Disposal Hull (FDH) Approaches

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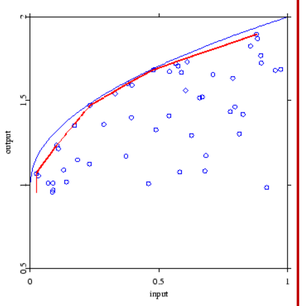
Background

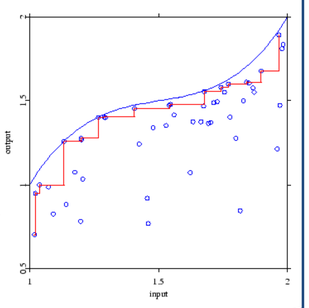
The public bus system in Athens, Greece is considered the core of the overall transportation system. Buses are widely used by the majority of the Greek population. Due to high demand on the use of public transportation in Greece, it is of utmost importance to be managed as efficiently as possible. The measurement of efficiency of each transportation mode separately and overall as a system is not only a powerful management tool for transportation operations in order to achieve the maximum possible performance and productivity, but also an informative input for future transportation planning. Among other methods, the efficiency of bus routes on a public transportation system can be analyzed by Data Envelopment Analysis (DEA) and by Free Disposal Hull (FDH) models. The proposed modelling approaches could be used to distinguish bus lines that are relatively efficient from the ones that need to be improved to achieve efficiency. Both methods were applied to evaluate 93 bus lines in Athens, Greece. After the calculation of the efficiency, the results of each method applied were compared and analyzed regarding their differences.

DEA vs FDH

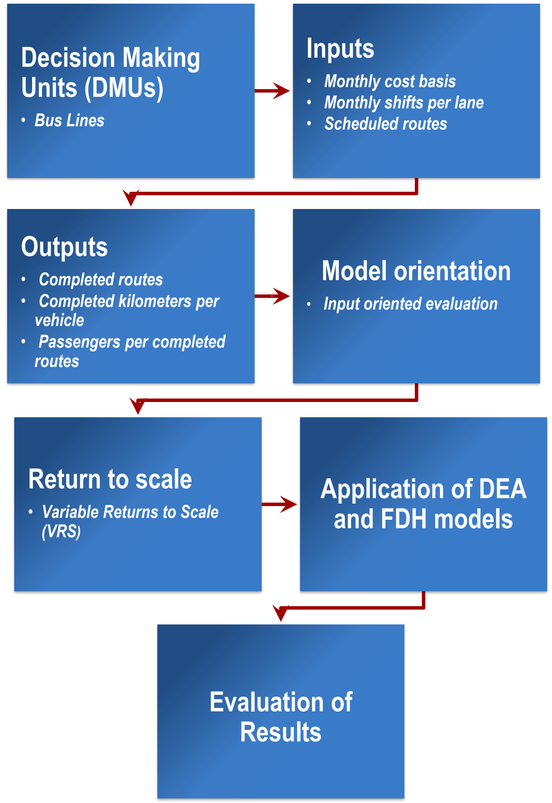
Data Envelopment Analysis (DEA) *is a non-parametric method, used in operations research for the estimation of the production frontiers. It is frequently used to empirically measure the productive efficiency of Decision Making Units (or DMUs) with multiple outputs and inputs.*



Free Disposal Hull (FDH) is also a deterministic, non-parametric method, requiring minimal assumptions with respect to the production technology. The FDH model was firstly designed as an alternative method to the data envelopment analysis (DEA) model, where only the strong (free) disposability of inputs and outputs is assumed.



Evaluation Steps

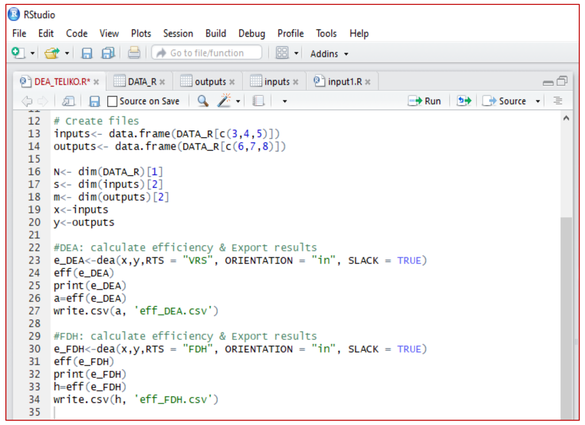


- Decision Making Unit is the object that is evaluated. In the present study the Decision making units are public bus lines.
- The data necessary for the evaluation are distinguished in the resources of the bus lines (inputs) and the products of the operation of bus lines (outputs).
- Considered inputs: the total cost per month, the monthly number of shifts and the number of scheduled routes per month for each bus line.
- Considered outputs: the monthly number of completed routes, completed kilometers per vehicle and passengers per completed route.
- The next step is the orientation of the model. The model will be either input oriented or output oriented. The orientation used is for inputs, because the desirable outcome is the use of as many as less resource (inputs) for a certain level production (outputs).
- The definition of returns to scale is essential for the evaluation. The Variable returns to Scale is the most appropriate choice, since any change in inputs does not result in a proportional change in the outputs.
- The DEA and FDH models are applied in order to extract the efficiency results for each bus line.
- The efficiency results of each model are evaluated and compared.

Case Study

- Project early phase considered efficiency evaluation of ninety-three (93) bus lines of the Public Transportation System in the capital of Greece, Athens.
- Due to lack of sufficient input and/or output data, the case study's scope was restricted to the evaluation of sixteen (16) bus lines in total, recognized by Athens Department of Transportation as the most crucial ones in public transit network.

- The DEA and FDH models evaluated the efficiency of each bus line utilizing different combinations of considered inputs with all considered outputs. The four different scenarios conducted are presented below.
  I. Monthly cost, number of shifts and scheduled bus routes as inputs;
  II. Monthly cost as input;
  III. Monthly number of shifts as input;
  IV. Monthly scheduled bus routes as input.
- The application of the DEA and FDH models for the bus lines' evaluation was performed using programming language R studio. The following figure presents the code applied for the evaluation of both methods, in order to extract the efficiency results.



RStudio

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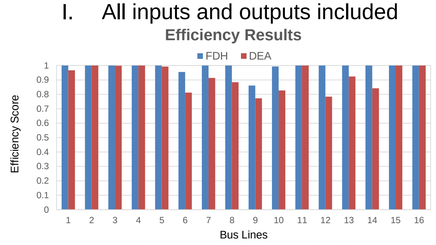
DEA_TELIKO.R* | DATA_R | outputs | inputs | input1.R

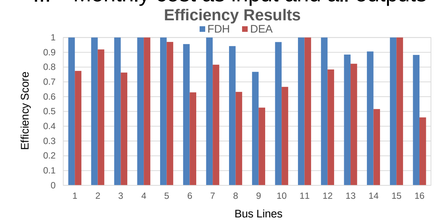
```
# Create files
inputs<- data.frame(DATA_R[c(3,4,5)])
outputs<- data.frame(DATA_R[c(6,7,8)])

N<- dim(DATA_R)[1]
s<- dim(inputs)[2]
m<- dim(outputs)[2]
x<-inputs
y<-outputs

#DEA: calculate efficiency & Export results
e_DEA<-dea(x,y,RTS = "VRS", ORIENTATION = "in", SLACK = TRUE)
eff(e_DEA)
print(e_DEA)
a=eff(e_DEA)
write.csv(a, 'eff_DEA.csv')

#FDH: calculate efficiency & Export results
e_FDH<-dea(x,y,RTS = "FDH", ORIENTATION = "in", SLACK = TRUE)
eff(e_FDH)
print(e_FDH)
h=eff(e_FDH)
write.csv(h, 'eff_FDH.csv')
```

Evaluation Results

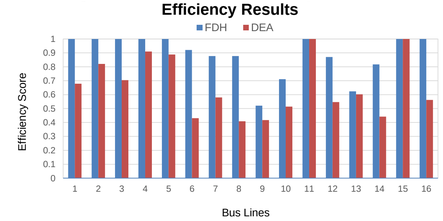
I. All inputs and outputs included



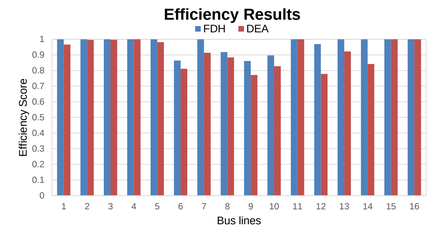
II. Monthly cost as input and all outputs



III. Monthly number of shifts as input and all outputs



IV. Monthly scheduled bus routes as input and all outputs



Conclusions

- The results for all four analyzed cases suggest that the majority of bus lines are not efficient, but at the same time very close to the efficiency frontier.
- Analysis of the efficiency yielded by DEA model and the FDH model confirms that the DEA and FDH methodologies tend to give significantly different results.
- The DEA model is considered , since the FDH model is more likely to identify as efficient some DMUs that are not performing well.
- In this respect, DEA has greater potential to provide efficient goals for the DMUs to work towards.
- Further research regarding the effectiveness and the service of each bus line and overall as a transport system would lead to a complete evaluation.